pH History and Potential Development for 1996 and 1998 Water Samples from Selected Piezometers at South Bay

December 2000

pH HISTORY and POTENTIAL pH DEVELOPMENT
for 1996 and 1998 WATER SAMPLES from SELECTED PIEZOMETERS at SOUTH BAY

pH History

Water samples were collected from selected piezometers in the tailings basin at South Bay in September 1996 and June 1998. Values of pH and other physical parameters were measured in the fields and in the laboratory shortly after sampling; pH values in the stored samples were measured again in May1999 and September 2000. The results are listed in Table 1A; the changes in pH, Eh, and conductivity of two selected samples are shown in Figures 1A and 1B; the changes in pH vs. time for all samples from Table 1A are shown in Figures 2A and 2B (File PZWATER.XLS). Results in Table 2 show the changes of water pH, which were kept in open jars with an intermittent stirring condition (File pH history 12Oct2000.xls).

Median values of pH, Eh, and conductivity for each measurement date are shown for the 1996 and 1998 samples in Figures 3A and 3B, respectively (File PZSELECT.XLS).

The progressive lowering of the pH, and increases in Eh and conductivity, in Fe-bearing samples over time reflect oxidation of Fe^{2+} to Fe^{3+}, and precipitation of ferric hydroxide and/or jarosite. Oxidation will have occurred in the water samples by slow transfer of oxygen through the walls of the polyethylene bottles in which the samples were stored. It is highly unlikely that any neutralization of acidity occurred in the sealed water samples during cold and dark storage. It should be noted that the pH of two samples, with low Fe content (< 3 ppm), increased during storage.

Potential pH Development

The various reactions involved in the generation of acidity can be summarized as follows:

A. OXIDATION of PYRITE / PRECIPITATION of FERRIC HYDROXIDE

1 - <u>Pyrite Oxidation:</u> $FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$
1 mole FeS_2 produces: **2** moles of H^+ or
1 mole of acidity (as $CaCO_3$)

2 - <u>Ferrous Ion Oxidation:</u> $Fe^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O$
1 mole Fe^{2+} consumes: **1** mole of H^+ or
0.5 mole of acidity (as $CaCO_3$)

3 - <u>Ferric Ion Hydrolysis:</u> $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3(s) + 3H^+$
1 mole Fe^{3+} produces: **3** moles of H^+ or
1.5 moles of acidity (as $CaCO_3$)

<u>NET ACID PRODUCTION:</u>
1 mole pyrite produces: **4** moles of H^+ or
2 moles of acidity (as $CaCO_3$)

B. OXIDATION of PYRITE / PRECIPITATION of K-JAROSITE

1 - <u>Pyrite Oxidation:</u> $FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$

1 mole FeS_2 produces: **2** moles of H^+ or
1 mole of acidity (as $CaCO_3$)

2 - <u>Ferrous Ion Oxidation:</u> $Fe^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O$

1 mole Fe^{2+} consumes: **1** mole of H^+ or
0.5 mole of acidity (as $CaCO_3$)

3 - K-<u>Jarosite Precipitation:</u> $3Fe^{3+} + K^+ + 2SO_4^{2-} + 6H_2O \rightarrow KFe_3(SO_4)_2(OH)_6(s) + 6H^+$

1 mole Fe^{3+} produces: **2** moles of H^+ or
1 mole of acidity (as $CaCO_3$)

<u>NET ACID PRODUCTION:</u>

1 mole pyrite produces: **3** moles of H^+ or
1.5 moles of acidity (as $CaCO_3$)

C. OXIDATION of PYRRHOTITE / PRECIPITATION of FERRIC HYDROXIDE

1 - <u>Pyrrhotite Oxidation:</u> $FeS + 7/4O_2 + 1/2H_2O \rightarrow Fe^{2+} + SO_4^{2-} + H^+$

1 mole FeS produces: **1** mole of H^+ or
0.5 mole of acidity (as $CaCO_3$)

2 - <u>Ferrous Ion Oxidation:</u> $Fe^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O$

1 mole Fe^{2+} consumes: **1** mole of H^+ or
0.5 mole of acidity (as $CaCO_3$)

3 - <u>Ferric Ion Hydrolysis:</u> $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3(s) + 3H^+$

1 mole Fe^{3+} produces: **3** moles of H^+ or
1.5 moles of acidity (as $CaCO_3$)

<u>NET ACID PRODUCTION:</u>

1 mole of Pyrrhotite produces: **3** moles of H^+ or
1.5 moles of acidity (as $CaCO^3$)

D. OXIDATION of PYRRHOTITE / PRECIPITATION of K-JAROSITE

1 - <u>Pyrrhotite Oxidation:</u> $FeS + 7/4O_2 + 1/2H_2O \rightarrow Fe^{2+} + SO_4^{2-} + H^+$

1 mole FeS produces: **1** mole of H^+ or
0.5 mole of acidity (as $CaCO_3$)

2 - <u>Ferrous Ion Oxidation:</u> $Fe^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O$

1 mole Fe^{2+} consumes: **1** mole of H^+ or
0.5 mole of acidity (as $CaCO_3$)

3 - K-<u>Jarosite Precipitation:</u> $3Fe^{3+} + K^+ + 2SO_4^{2-} + 6H_2O \rightarrow KFe_3(SO_4)_2(OH)_6(s) + 6H^+$

1 mole Fe^{3+} produces: **2** moles of H^+ or
1 mole of acidity (as $CaCO_3$)

<u>NET ACID PRODUCTION:</u>

1 mole pyrite produces: **2** moles of H^+ or
1 mole of acidity (as $CaCO_3$)

In general, the reactions numbered '**1**' will not have contributed to lowering of the pH in the various high-Fe water samples, because the filtered water samples presumably did not contain any metal-sulphides. Therefore only the following increases in $[H^+]$ (lowering the pH) could be expected for each mole of Fe contained in the samples.

I - if only Fe^{2+} was present, was oxidized, and K-jarosite precipitated - 1 mole H^+
II - if only Fe^{2+} was present, was oxidized and ferric hydroxide precipitated - 2 moles H^+
III - if only Fe^{3+} was present, and K-jarosite precipitated - 2 moles H^+
IV - if only Fe^{3+} was present, and ferric hydroxide precipitated - 3 moles H^+

The first section of Table 2, for selected 1966 'whole acidified' and 'filtered acidified' samples, lists ppm concentrations of Ca, Fe, and S; field and laboratory values of pH, conductivity, and Eh; original $[H^+]$ in moles; and [Ca], [Fe], and [S] in millimoles.

The section named "pH HISTORY" lists 1996 field pH, 1966 lab pH, 1999 pH for stored 1998 samples from the same piezometers, and 1999 and 2000 pH for the stored 1996 samples. The section named "POTENTIAL pH DEVELOPMENT" lists pH values that could potentially have developed as a result of the processes shown in I - IV above, unless some equilibrium was reached before the various reactions went to completion. The pH history and potential pH developments are shown in Figure 4 (FILE NEWTABLE2.XLW) for four selected samples, and in Figure 5 (FILE NEWTABLE2.XLW) for all the samples listed in Table 2 (FILE NEWTABLE2.XLW). It is obvious from these results that the oxidation/precipitation reactions have not gone to completion in any of the samples.

Simulations using PHREEQC were carried out for all samples (except H2 for which insufficient data were available), to determine final pH and amount of goethite precipitated when equilibrium with O_2, CO_2 and goethite precipitate is reached. K-jarosite appeared not to be the most likely precipitate. Comparison of the results of the simulations with the latest measured pH values suggests that the final pH and equilibrium with goethite precipitate have been reached in only one or two samples.

The solubility of K-jarosite (log Ksp = -11.0 ± 0.3 at 25^oC; Baron and Palmer, 1996) is low enough that re-dissolution of K-jarosite would be unlikely, unless pH were to drop further due to some unforeseen effect.

Conclusion and Recommendations

The pH values in stored Fe-bearing water samples from the South Bay tailings basin have not yet reached their lowest possible level. The oxidation/precipitation reactions in the water samples have apparently not gone to completion. They may, however, have reached equilibrium under the prevailing conditions; geochemical calculations would be necessary to determine if that is the case.

It could be useful to open selected samples directly to the atmosphere and determine pH after a further period of exposure to available oxygen, to determine how close to completion the reactions may eventually come.

It may also be useful to analyse the precipitates formed in the sample bottles to determine whether the predominant precipitate is Fe-hydroxide or jarosite.

Reference

Baron, D. and Palmer, C.D., 1996. Solubility of jarosite at 4-35 □C. Geochimica et Cosmochimica Acta, Vol. 60, No. 2, pp.185-195.

8 December, 2000

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-4	8-09-96	8-09-96	field	aft	165	413	3.84	4470	15.0	5588	0.5
		11-09-96	lab	aft	409	661	3.33	3650	8.3	5480	3
		20-09-96	lab	aft	388	632	3.22	3350	20.9	3649	12
		3-May-99	lab	aft	614	856	2.10	5990	22.8	6266	967
		15-Sep-00	lab	aft		874	1.93	7380	22.3	7801	1468
M-5E	8-09-96	8-09-96	field	aft	32	280	5.60	3940	14.2	5026	0.5
		11-09-96	lab	aft	164	417	5.06	2520	7.5	3877	3
		20-09-96	lab	aft	365	609	3.44	2850	20.9	3105	12
		3-May-99	lab	aft	608	851	2.27	5360	22.6	5630	967
		15-Sep-00	lab	aft		836	1.933	6380	22.9	6660	1468
M-5W	8-09-96	8-09-96	field	aft	25	273	4.97	5690	14.5	7203	0.5
		11-09-96	lab	aft	247	500	3.82	12600	7.5	19385	3
		20-09-96	lab	aft	319	563	3.42	13500	21.0	14674	12
		3-May-99	lab	aft	604	847	1.99	16330	22.2	17299	967
		15-Sep-00	lab	aft		874	1.63	21100	22.6	22164	1468
M-5N	8-09-96	8-09-96	field	aft	-65	184	5.69	5220	13.5	6779	0.5
		11-09-96	lab	aft	110	362	5.29	3810	8.1	5755	3
		20-09-96	lab	aft	261	505	4.47	4200	20.9	4575	12
		3-May-99	lab	aft	614	857	2.06	7340	22.6	7710	967
		15-Sep-00	lab	aft		no sample left					1468
M-7N	8-09-96	8-09-96	field	aft	150	398	4.19	8100	14.5	10253	0.5
		11-09-96	lab	aft	226	479	4.15	5000	7.0	7813	3
		20-09-96	lab	aft	306	550	3.74	5600	20.9	6100	12
		3-May-99	lab	aft	467	710	2.29	7540	22.1	8004	967
		15-Sep-00	lab	aft		714	1.92	9180	22.4	9684	1468

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-7S	8-09-96	8-09-96	field	aft	184	432	3.65	11480	14.5	14532	0.5
		11-09-96	lab	aft	211	461	3.89	7800	11.0	10833	3
		20-09-96	lab	aft	310	554	3.57	8100	21.0	8804	12
		3-May-99	lab	aft	399	642	2.24	11640	22.2	12331	967
		15-Sep-00	lab	aft		713	1.89	10560	22.6	11092	1468
M-9	8-09-96	8-09-96	field	aft	220	469	3.76	5380	13.6	6969	0.5
		11-09-96	lab	aft	263	516	3.73	4460	7.0	6969	3
		20-09-96	lab	aft	361	605	3.28	5200	21.1	5640	12
		3-May-99	lab	aft	613	856	2.22	6900	22.2	7309	967
		15-Sep-00	lab	aft		766	1.83	9630	22.9	10052	1468
M-24W	8-09-96	8-09-96	field	aft	54	303	5.09	5450	13.3	7115	0.5
		11-09-96	lab	aft	114	366	5.16	3600	9.0	5294	3
		20-09-96	lab	aft	293	537	4.04	3750	21.0	4076	12
		3-May-99	lab	aft	538	781	2.03	7220	22.5	7600	967
		15-Sep-00	lab	aft		857	1.82	8070	22.9	8424	1468
M-24E	8-09-96	8-09-96	field	aft	82	331	4.72	6490	12.3	8700	0.5
		11-09-96	lab	aft	136	387	5.15	5000	10.5	7042	3
		20-09-96	lab	aft	309	553	3.91	4950	21.0	5380	12
		3-May-99	lab	aft	445	688	2.12	8300	22.6	8718	967
		15-Sep-00	lab	aft		744	1.79	9280	23.1	9647	1468
M-24C	8-09-96	8-09-96	field	aft	105	354	4.97	2290	12.2	3078	0.5
		11-09-96	lab	aft	162	414	4.73	1420	8.0	2152	3
		20-09-96	lab	aft	376	620	3.66	1600	20.8	1747	12
		3-May-99	lab	aft	567	809	2.37	3650	23.2	3786	967
		15-Sep-00	lab	aft		no sample left					1468

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-27N	8-09-96	8-09-96	field	aft	181	429	3.57	5820	14.5	7367	0.5
		11-09-96	lab	aft	201	455	3.78	7200	5.9	11650	3
		20-09-96	lab	aft	332	576	3.37	7800	21.0	8478	12
		3-May-99	lab	aft	400	643	2.17	11880	22.3	12558	967
		15-Sep-00	lab	aft		868	1.76	11140	22.9	11628	1468
M-27S	8-09-96	8-09-96	field	aft	21	269	5.09	5910	13.8	7616	0.5
		11-09-96	lab	aft	158	410	4.66	8000	7.8	12195	3
		20-09-96	lab	aft	311	555	3.52	8000	20.9	8715	12
		3-May-99	lab	aft	386	629	2.24	12780	22.2	13538	967
		15-Sep-00	lab	aft		683	1.85	11060	22.9	11545	1468
M-27C	8-09-96	8-09-96	field	aft	-83	165	6.06	2790	14.4	3541	0.5
		11-09-96	lab	aft	40	293	6.00	1800	7.5	2769	3
		20-09-96	lab	aft	261	505	4.64	2000	20.9	2179	12
		3-May-99	lab	aft	557	799	2.32	4230	23.1	4397	967
		15-Sep-00	lab	aft		800	2.12	4620	23.1	4802	1468
M-32	8-09-96	8-09-96	field	aft	-57	192	5.37	6350	12.4	8489	0.5
		11-09-96	lab	aft	72	325	5.51	4290	7.5	6600	3
		20-09-96	lab	aft	279	523	4.42	4350	21.0	4728	12
		3-May-99	lab	aft	540	783	2.26	8210	22.3	8679	967
		15-Sep-00	lab	aft		834	1.79	9410	22.8	9843	1468
M-40A	8-09-96	8-09-96	field	aft	272	520	3.02	3690	14.9	4624	0.5
		11-09-96	lab	aft	191	444	3.62	2490	7.5	3831	3
		20-09-96	lab	aft	428	672	3.16	2600	21.0	2826	12
		3-May-99	lab	aft	557	799	2.15	5590	23.1	5811	967
		15-Sep-00	lab	aft		771	1.96	6140	22.9	6409	1468

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-40B											
M-43	8-09-96	8-09-96	field	aft	281	530	2.92	6190	13.6	8018	0.5
		11-09-96	lab	aft	251	502	3.38	6200	9.1	9091	3
		20-09-96	lab	aft	356	600	3.24	6000	21.0	6522	12
		3-May-99	lab	aft	421	664	2.35	8980	22.3	9493	967
		15-Sep-00	lab	aft		771	1.79	9940	22.9	10376	1468
M-46	8-09-96	8-09-96	field	aft	210	459	4.57	5770	12.9	7612	0.5
		11-09-96	lab	aft	183	435	4.35	6700	9.0	9853	3
		20-09-96	lab	aft	288	533	3.64	6100	19.1	6916	12
		3-May-99	lab	aft	424	667	2.27	9810	22.4	10348	967
		15-Sep-00	lab	aft		864	1.77	10810	23.0	11260	1468
M-64	8-09-96	8-09-96	field	aft	307	554	2.82	1460	15.9	1785	0.5
		11-09-96	lab	aft	256	504	3.27	1100	14.0	1410	3
		20-09-96	lab	aft	445	692	3.39	1000	16.0	1220	12
		3-May-99	lab	aft	563	805	2.55	1980	24.0	2020	967
		15-Sep-00	lab	aft		730	2.51	2310	22.9	2411	1468
M-72A	8-09-96	8-09-96	field	aft	-105	143	6.33	1300	13.9	1671	0.5
		11-09-96	lab	aft	-26	227	6.26	800	7.5	1231	3
		20-09-96	lab	aft	91	339	5.62	820	15.1	1022	12
		3-May-99	lab	aft	484	725	3.09	1346	24.3	1365	967
		15-Sep-00	lab	aft		725	2.99	1560	23.2	1618	1468

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-72B	8-09-96	8-09-96	field	aft	-54	194	5.67	6050	13.8	7796	0.5
		11-09-96	lab	aft	-20	231	5.80	6400	9.5	9275	3
		20-09-96	lab	aft	20	267	5.57	5700	15.4	7054	12
		3-May-99	lab	aft	428	671	2.25	10690	22.7	11205	967
		15-Sep-00	lab	aft		840	1.89	11640	22.9	12150	1468
M-72C	8-09-96	8-09-96	field	aft	120	368	4.37	6040	15.1	7531	0.5
		11-09-96	lab	aft	164	415	4.30	6300	9.9	9026	3
		20-09-96	lab	aft	279	526	3.89	7100	15.9	8680	12
		3-May-99	lab	aft	397	639	2.11	13120	24.1	13360	967
		15-Sep-00	lab	aft		825	1.79	12370	23.0	12885	1468
M-75	8-09-96	8-09-96	field	aft	-108	140	6.05	4510	13.9	5797	0.5
		11-09-96	lab	aft	-55	199	6.12	940	5.8	1526	3
		20-09-96	lab	aft	99	346	5.42	2650	15.8	3248	12
		3-May-99	lab	aft	573	814	2.34	5680	24.3	5761	967
		15-Sep-00	lab	aft		812	2.04	6240	23.0	6500	1468
M-83A	8-09-96	8-09-96	field	aft	-79	169	6.02	3280	13.7	4238	0.5
		11-09-96	lab	aft	-39	213	6.04	1970	7.6	3021	3
		20-09-96	lab	aft	41	287	5.82	1990	17.1	2363	12
		3-May-99	lab	aft	574	815	2.39	4320	24.6	4355	967
		15-Sep-00	lab	aft		790	2.23	4890	22.3	5169	1468
M-89	8-09-96	8-09-96	field	aft	347	595	3.05	900	14.2	1148	0.5
		11-09-96	lab	aft	415	668	3.36	540	7.5	831	3
		20-09-96	lab	aft	541	786	3.48	600	18.3	693	12
		3-May-99	lab	aft	492	733	3.07	976	24.5	986	967
		15-Sep-00	lab	aft		729	2.95	1107	23.2	1148	1468

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
H-1	8-09-96	8-09-96	field	aft	-43	204	5.61	4270	15.2	5311	0.5
		11-09-96	lab	aft	274	525	4.16	2600	9.5	3768	3
		20-09-96	lab	aft	380	624	3.42	3200	20.7	3501	12
		3-May-99	lab	aft	587	830	2.25	6690	22.6	7027	967
		15-Sep-00	lab	aft		855	1.45	7400	22.5	7789	1468
H-2	8-09-96	8-09-96	field	aft	-89	158	5.84	5430	15.3	6737	0.5
		11-09-96	lab	aft	-83	170	5.68	3040	6.2	4872	3
		20-09-96	lab	aft	268	512	4.44	3850	21.0	4185	12
		3-May-99	lab	aft	364	607	2.67	6040	22.4	6371	967
		15-Sep-00	lab	aft		846	1.84	7790	23.0	8115	1468
H-3											
H-4											
H-5	8-09-96	8-09-96	field	aft	94	341	4.63	5110	15.2	6356	0.5
		11-09-96	lab	aft	184	436	4.65	3000	7.8	4573	3
		20-09-96	lab	aft	307	551	3.91	3750	21.1	4067	12
		3-May-99	lab	aft	601	844	2.34	6130	22.3	6480	967
		15-Sep-00	lab	aft		849	1.91	7240	23.0	7542	1468

Table 1A: History of Physical Parameters of Selected Water Samples from Piezometers (cont)

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
H-6	8-09-96	8-09-96	field	aft	-29	219	5.36	10200	14.9	12782	0.5
		11-09-96	lab	aft	-17	234	5.07	6800	10.1	9687	3
		20-09-96	lab	aft	294	538	3.97	8000	21.2	8658	12
		3-May-99	lab	aft	413	656	2.20	11140	22.6	11702	967
		15-Sep-00	lab	aft		745	1.79	11040	22.8	11548	1468
H-7	8-09-96	8-09-96	field	aft	-49	198	5.52	5420	15.9	6626	0.5
		11-09-96	lab	aft	-30	222	5.45	3120	9.0	4588	3
		20-09-96	lab	aft	265	509	4.62	385	21.1	418	12
		3-May-99	lab	aft	598	841	2.20	7100	22.7	7442	967
		15-Sep-00	lab	aft		853	1.86	8210	22.4	8660	1468
H-8	8-09-96	8-09-96	field	aft	14	261	4.82	14310	15.9	17494	0.5
		11-09-96	lab	aft	256	507	4.68	9300	9.9	13324	3
		20-09-96	lab	aft	299	543	3.74	11300	21.1	12256	12
		3-May-99	lab	aft	374	616	2.18	16080	22.9	16785	967
		15-Sep-00	lab	aft		657	1.84	1430	23.0	1490	1468

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-4	10-06-98	10-06-98	field	aft	240	488	3.50	4950	14.5	6266	1
		24-06-98	lab	aft	219	463	3.50	5580	20.4	6145	14
		3-May-99	lab	aft	360	611	2.94	6360	9.8	9138	327
		15-Sep-00	lab	aft		654	2.06	6910	23.0	7198	828
M-5E	10-06-98	10-06-98	field	aft	165	413	4.84	2830	14.0	3628	1
		24-06-98	lab	aft	157	401	4.00	2670	19.9	2973	14
		3-May-99	lab	aft	404	647	2.64	3470	22.2	3676	327
		15-Sep-00	lab	aft		518	2.10	761	22.2	806	828
M-5W	10-06-98	10-06-98	field	aft	125	373	4.42	12500	14.0	16026	1
		24-06-98	lab	aft	192	436	3.81	15740	20.4	17335	14
		3-May-99	lab	aft	302	545	2.90	18420	21.9	19638	327
		15-Sep-00	lab	aft		573	2.11	20200	22.2	21398	828
M-5N	10-06-98	10-06-98	field	aft	245	494	3.31	4360	13.5	5662	1
		24-06-98	lab	aft	265	509	3.28	4320	20.5	4747	14
		3-May-99	lab	aft	377	na	2.91	na	na	na	327
		15-Sep-00	lab	aft		no sample left					828
M-7N	10-06-98	10-06-98	field	aft	67	316	5.24	7200	13.0	9474	1
		24-06-98	lab	aft	68	312	4.94	6800	20.2	7522	14
		3-May-99	lab	aft	341	584	2.77	10220	22.0	10872	327
		15-Sep-00	lab	aft		776	1.85	8970	22.6	9422	828

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-7S	10-06-98	10-06-98	field	aft	58	307	5.26	8000	13.0	10526	1
		24-06-98	lab	aft	37	281	5.31	8210	20.4	9042	14
		3-May-99	lab	aft	329	572	2.79	10410	22.0	11074	327
		15-Sep-00	lab	aft		603	2.04	11190	22.2	11854	828
M-9	10-06-98	10-06-98	field	aft	159	408	4.21	4800	12.5	6400	1
		24-06-98	lab	aft	136	381	3.94	3630	19.5	4079	14
		3-May-99	lab	aft	352	595	2.78	6650	22.4	7015	327
		15-Sep-00	lab	aft		639	2.08	7660	22.3	8097	828
M-24W	10-06-98	10-06-98	field	aft	58	306	5.43	3800	14.0	4872	1
		24-06-98	lab	aft	60	304	5.08	3650	20.4	4020	14
		3-May-99	lab	aft	379	622	2.71	5100	22.4	5380	327
		15-Sep-00	lab	aft		739	1.88	7010	22.4	7395	828
M-24E	10-06-98	10-06-98	field	aft	175	425	4.60	3850	12.0	5203	1
		24-06-98	lab	aft	132	377	4.30	3250	19.4	3660	14
		3-May-99	lab	aft	369	612	2.76	4940	22.7	5178	327
		15-Sep-00	lab	aft		666	2.00	6540	22.2	6928	828
M-24C	10-06-98	10-06-98	field	aft	189	438	3.79	600	12.5	800	1
		24-06-98	lab	aft	251	498	3.49	797	16.6	958	14
		3-May-99	lab	aft	562	812	3.02	1150	11.7	1567	327
		15-Sep-00	lab	aft		no sample left					828

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-27N	10-06-98	10-06-98	field	aft	222	471	3.64	7500	13.0	9868	1
		24-06-98	lab	aft	203	447	3.67	9200	20.2	10177	14
		3-May-99	lab	aft	325	568	2.82	10000	22.2	10593	327
		15-Sep-00	lab	aft		597	2.06	11050	22.4	11656	828
M-27S	10-06-98	10-06-98	field	aft	193	442	4.15	7500	13.0	9868	1
		24-06-98	lab	aft	187	431	3.93	8190	20.1	9080	14
		3-May-99	lab	aft	330	573	2.79	9260	22.3	9789	327
		15-Sep-00	lab	aft		604	2.05	10190	22.3	10772	828
M-27C	10-06-98	10-06-98	field	aft	50	299	5.91	2190	13.5	2844	1
		24-06-98	lab	aft	-14	232	5.88	2450	17.2	2903	14
		3-May-99	lab	aft	509	759	2.83	2980	11.1	4127	327
		15-Sep-00	lab	aft		730	2.09	5060	23.2	5249	828
M-32	10-06-98	10-06-98	field	aft	60	309	5.58	4020	12.5	5360	1
		24-06-98	lab	aft	-33	211	5.86	2670	20.2	2954	14
		3-May-99	lab	aft	363	613	2.92	5580	11.3	7686	327
		15-Sep-00	lab	aft		686	1.98	7370	23.3	7629	828
M-40A	10-06-98	10-06-98	field	aft	202	451	3.49	2750	13.0	3618	1
		24-06-98	lab	aft	215	459	3.69	3290	20.5	3615	14
		3-May-99	lab	aft	391	641	2.87	4000	11.2	5525	327
		15-Sep-00	lab	aft		752	2.01	6460	22.0	6872	828

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-40B	10-06-98	10-06-98	field	aft	80	330	5.39	6000	12.0	8108	1
		24-06-98	lab	aft	23	267	5.43	6180	20.4	6806	14
		3-May-99	lab	aft	352	595	2.74	7670	22.4	8091	327
		15-Sep-00	lab	aft		631	1.96	9980	22.1	10594	828
M-43	10-06-98	10-06-98	field	aft	144	393	3.78	6100	13.0	8026	1
		24-06-98	lab	aft	200	444	3.67	7300	20.0	8111	14
		3-May-99	lab	aft	340	583	2.79	7940	22.4	8376	327
		15-Sep-00	lab	aft		616	2.06	8980	22.2	9513	828
M-46	10-06-98	10-06-98	field	aft	202	450	3.60	6900	15.0	8625	1
		24-06-98	lab	aft	208	452	3.67	7950	20.2	8794	14
		3-May-99	lab	aft	338	580	2.79	8740	22.8	9142	327
		15-Sep-00	lab	aft		612	2.05	9860	21.9	10512	828
M-64	10-06-98	10-06-98	field	aft	195	442	4.36	650	15.5	802	1
		24-06-98	lab	aft	268	514	3.61	746	17.0	888	14
		3-May-99	lab	aft	527	778	3.36	964	10.0	1377	327
		15-Sep-00	lab	aft		675	2.99	1085	23.2	1126	828
M-72A	10-06-98	10-06-98	field	aft	-18	229	6.31	1050	16.0	1280	1
		24-06-98	lab	aft	-20	225	6.24	1022	19.1	1159	14
		3-May-99	lab	aft	493	743	3.26	1432	11.0	1989	327
		15-Sep-00	lab	aft		656	2.89	1425	23.0	1484	828

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
M-72B	10-06-98	10-06-98	field	aft	35	284	5.60	7000	13.0	9211	1
		24-06-98	lab	aft	-4	241	5.47	4060	19.6	4552	14
		3-May-99	lab	aft	303	545	2.95	9860	23.1	10249	327
		15-Sep-00	lab	aft		612	2.10	10460	22.3	11057	828
M-72C	10-06-98	10-06-98	field	aft	213	461	4.08	5500	15.0	6875	1
		24-06-98	lab	aft	155	400	3.83	4280	19.1	4853	14
		3-May-99	lab	aft	345	594	2.95	8000	12.8	10582	327
		15-Sep-00	lab	aft		616	2.07	9790	23.1	10177	828
M-75	10-06-98	10-06-98	field	aft	20	269	6.14	3250	13.5	4221	1
		24-06-98	lab	aft	50	296	6.07	3440	17.2	4076	14
		3-May-99	lab	aft	384	633	2.96	3710	13.5	4818	327
		15-Sep-00	lab	aft		706	2.11	5510	23.3	5704	828
M-83A	10-06-98	10-06-98	field	aft	10	258	6.05	2250	14.0	2885	1
		24-06-98	lab	aft	-30	215	6.06	1775	18.9	2022	14
		3-May-99	lab	aft	509	758	2.99	2820	12.7	3740	327
		15-Sep-00	lab	aft		747	2.57	3280	23.2	3402	828
M-89	10-06-98	10-06-98	field	aft	263	510	3.49	280	16.0	341	1
		24-06-98	lab	aft	373	619	3.22	381	17.9	444	14
		3-May-99	lab	aft	502	750	3.51	401	14.4	509	327
		15-Sep-00	lab	aft		751	3.25	392	22.7	411	828

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
H-1	10-06-98	10-06-98	field	aft	-61	188	5.69	4180	13.5	5429	1
		24-06-98	lab	aft	-44	202	5.91	4290	18.0	4988	14
		3-May-99	lab	aft	370	613	2.69	5370	22.7	5629	327
		15-Sep-00	lab	aft		682	1.92	6550	22.0	6968	828
H-2	10-06-98	10-06-98	field	aft	180	428	3.67	3400	14.0	4359	1
		24-06-98	lab	aft	-2	243	5.44	5950	19.2	6731	14
		3-May-99	lab	aft	357	600	2.72	6790	22.6	7132	327
		15-Sep-00	lab	aft		644	1.95	7910	22.1	8397	828
H-3	10-06-98	10-06-98	field	aft	146	394	4.13	3580	14.0	4590	1
		24-06-98	lab	aft	162	406	3.87	4010	20.8	4378	14
		3-May-99	lab	aft	358	608	2.92	5230	10.8	7304	327
		15-Sep-00	lab	aft		642	2.01	6810	23.1	7079	828
H-4	10-06-98	10-06-98	field	aft	360	611	2.94	6360	9.8	9138	1
		24-06-98	lab	aft	219	463	3.37	3550	21.2	3842	14
		3-May-99	lab	aft	357	608	3.02	4290	10.5	6042	327
		15-Sep-00	lab	aft		587	2.55	5490	23.2	5695	828
H-5	10-06-98	10-06-98	field	aft	208	457	3.43	3140	13.5	4078	1
		24-06-98	lab	aft	205	449	3.36	3520	20.4	3877	14
		3-May-99	lab	aft	450	693	2.72	3810	22.6	4002	327
		15-Sep-00	lab	aft		783	2.05	6190	22.2	6557	828

Piezo	Sample date	measured		before/after	Em	Eh	pH	Cond.	T	C@25	Elapsed time
		date	place	bailing	mV	mV	units	(uS/cm)	(^{o}C)	uS/cm	days
H-6	10-06-98	10-06-98	field	aft	40	289	5.74	4670	13.0	6145	1
		24-06-98	lab	aft	-46	199	5.80	5400	19.5	6067	14
		3-May-99	lab	aft	352	595	2.79	6140	22.6	6450	327
		15-Sep-00	lab	aft		651	1.99	7960	22.2	8432	828
H-7	10-06-98	10-06-98	field	aft	32	281	6.06	2950	13.5	3831	1
		24-06-98	lab	aft	25	271	5.76	3220	17.7	3770	14
		3-May-99	lab	aft	408	651	2.76	3620	22.7	3795	327
		15-Sep-00	lab	aft		725	2.06	5860	22.2	6208	828
H-8	10-06-98	10-06-98	field	aft	-7	241	5.49	11800	14.0	15128	1
		24-06-98	lab	aft	132	376	4.39	14480	20.6	15877	14
		3-May-99	lab	aft	298	540	2.94	17270	23.3	17878	327
		15-Sep-00	lab	aft		558	2.18	19970	22.2	21155	828

Table 2 **CHARACTERISTICS OF SELECTED 1996 SAMPLES FROM SOUTH BAY TAILINGS AREA**

Sample date: **10 Sep.'96**

LAB #	Piez. #	Al ppm	Ca ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Na ppm	S ppm	SO4 ppm	Zn ppm	F*pH units	F*Cond uS/cm	F*Eh mV	L*pH units	L*Cond uS/cm
6249	H5	0.168	388	1440	26.1	174	21.1	33.2	1500	4494.39	10.1	4.63	5110	341	4.65	3000
6252	H8	30.9	387	9550		375	123	8.88	7260	21752.8	749	4.82	14310	261	4.68	9300
6174	M24W	0.7	393	2420	7.4	79	37.5	2.83	1840	5513.11	59.6	5.09	5450	303	5.16	3600
6180	M27N	0.384	362	7800	44.3	304	99.5	16	5410	16209.8	189	5.09	5910	21	4.66	8000
6181	M27S	1.75	331	7350	48.7	275	91	11.4	5030	15071.2	270	3.57	5820	429	3.78	7200
6158	M4	5.98	353	1400	21.5	110	43.6	9	1380	4134.83	81.2	3.84	4470	413	3.33	365
6193	M40A	0.74	400	698	9.8	59	16.8	3.44	1040	3116.11	17.7	3.02	3690	520	3.62	2490
6159	M5E	1.7	221	1250	10.7	83.5	36.2	4.89	1120	3355.81	265	5.69	5220	184	5.29	3810
6160	M5W	8.2	421	14300	39.5	408	280	8.6	10700	32060	4070	5.60	3940	280	5.06	2520
6163	M7N	4.19	370	4060	17.5	128	85.5	4.58	2790	8359.56	177	4.19	8100	398	4.15	5000
6162	M7S	1.01	419	4950	36.2	373	141	14.4	4970	14891.4	399	3.65	11480	432	3.89	7800
6150	H1		590	1340	18.2	68.6	24.7	5.23	1250	3745.32	1.83	5.61	4270	204	4.16	2600
6247	H2		448	1890					1670	5003.75		5.84	5430	158	5.68	3040
6248	H3	0.48	209	481	7.2	41.2	14.4	2.51	551	1650.94	2.94	6.10	2480	154	5.20	1390
6250	H6	5.75	390	5650	9.3	295	136	7.42	4920	14741.6	310	5.36	10200	219	5.07	6800
6251	H7	3.43	400	1470	6.5	117	37.2	4.4	1620	4853.94	95.8	5.52	5420	198	5.45	3120

CHARACTERISTICS OF SELECTED 1996 SAMPLES FROM SOUTH BAY TAILINGS AREA

						----------	---------- pH HISTORY	----------	----------	----------
L*Eh mV	**L*T** C	**Original [H+] of SAMPLE** mole/L	**[Fe]** mmol/L	**[S]** mmol/L	**[Ca]** mmol/L	**F*pH 1996** units	**L*pH 1996** units	**1999 pH '99 from '98** units	**1999 pH '99 from '96** units	**2000 pH '00 from '96**	**pH after equilibrium with CO2 O2, and goethite (PHREEQC)** units
436	7.8	2.34E-05	25.78	46.79	9.68	4.63	3.91	2.72	2.34	1.91	1.594
507	9.9	1.51E-05	171.00	226.45	9.66	4.82	3.74	2.94	2.18	1.84	1.120
366	9.0	8.13E-06	43.33	57.39	9.81	5.09	4.04	2.71	2.03	1.82	1.393
410	7.8	8.13E-06	139.67	168.75	9.03	3.57	3.37	2.82	2.17	1.76	1.145
455	5.9	2.69E-04	131.61	156.89	8.26	5.09	3.52	2.79	2.24	1.85	1.162
661	8.8	1.45E-04	25.07	43.04	8.81	3.84	3.22	2.94	2.10	1.93	1.552
444	7.5	9.55E-04	12.50	32.44	9.98	3.02	3.16	2.87	2.15	1.96	1.180
362	8.1	2.04E-06	22.38	34.93	5.51	5.60	3.44	2.64	2.27	1.93	1.609
417	7.5	2.51E-06	256.06	333.75	10.50	4.97	3.42	2.90	1.99	1.63	1.059
479	7.0	6.46E-05	72.70	87.02	9.23	4.19	3.74	2.77	2.29	1.85	1.255
461	11.0	2.24E-04	88.64	155.02	10.45	3.65	3.57	2.79	2.24	1.84	1.284
525	9.5	2.45E-06	23.99	38.99	14.72	5.61	3.42	2.69	2.25	1.45	1.592
170		1.45E-06	33.84	52.09	11.18	5.84	4.44	2.72	2.67	1.84	
422	8.8	7.94E-07	8.61	17.19	5.21	6.10	4.27	2.92		2.01	1.968
234	10.1	4.37E-06	101.17	153.46	9.73	5.36	3.97	2.79	2.20	1.79	1.234
222	9.0	3.02E-06	26.32	50.53	9.98	5.52	4.62	2.76	2.20	1.86	1.601

CHARACTERISTICS OF SELECTED 1996 SAMPLES FROM SOUTH BAY TAILINGS AREA

---------- POTENTIAL pH DEVELOPMENT ----------				----------	----------	----------	
IF all original [Fe] was FeII then pH could drop due to oxid.& precip. of Jarosite to pH, units	**IF all original [Fe] was FeII then pH could drop due to oxid.& hydrol. to Fe(OH)3** to pH, units	**IF all original [Fe] was FeIII then pH could drop due to precipitation of Jarosite** to pH, units	**IF all original [Fe] was FeIII then pH could drop due to hydrolysis to Fe(OH)3** to pH, units	**pH after PHREEQC equilibrium with CO2 O2, and goethite** units	**Goethite precipitate from PHREEQC** mole/L	**Goethite precipitate from PHREEQC** g/L	
1.588	1.287	1.287	1.111	1.594	0.02517	2.236	H5
0.767	0.466	0.466	0.290	1.120	0.13100	11.639	H8
1.363	1.062	1.062	0.886	1.393	0.04075	3.621	M24W
0.855	0.554	0.554	0.378	1.145	0.10790	9.587	M27N
0.880	0.579	0.579	0.403	1.162	0.10070	8.947	M27S
1.598	1.299	1.299	1.123	1.552	0.02436	2.164	M4
1.871	1.586	1.586	1.415	1.180	0.01245	1.106	M40A
1.650	1.349	1.349	1.173	1.609	0.02197	1.952	M5E
0.592	0.291	0.291	0.115	1.059	0.17830	15.842	M5W
1.138	0.837	0.837	0.661	1.255	0.06269	5.570	M7N
1.051	0.751	0.751	0.575	1.284	0.07798	6.929	M7S
1.620	1.319	1.319	1.143	1.592	0.02357	2.094	H1
1.471	1.169	1.169	0.993				H2
2.065	1.764	1.764	1.588	1.968	0.00860	0.764	H3
0.995	0.694	0.694	0.518	1.234	0.08584	7.627	H6
1.580	1.279	1.279	1.103	1.601	0.02575	2.288	H7
			GFW for goethite		88.850		

CHARACTERISTICS OF SELECTED 1996 SAMPLES FROM SOUTH BAY TAILINGS AREA

Piez. #	Al epm	Ca epm	Fe epm	K epm	Mg epm	Mn epm	Na epm	S epm	SO4 epm	Zn epm	SUM Cations epm	Balance Error %
H5	0	0	0	0	0	0	0	0	93.5731	0	0.00	#DIV/0!
H8	0	0	0	0	0	0	0	0	452.894	0	0.00	#DIV/0!
M24W	0	0	0	0	0	0	0	0	114.783	0	0.00	#DIV/0!
M27N	0	0	0	0	0	0	0	0	337.487	0	0.00	#DIV/0!
M27S	0	0	0	0	0	0	0	0	313.782	0	0.00	#DIV/0!
M4	0	0	0	0	0	0	0	0	86.0873	0	0.00	#DIV/0!
M40A	0	0	0	0	0	0	0	0	64.8774	0	0.00	#DIV/0!
M5E	0	0	0	0	0	0	0	0	69.8679	0	0.00	#DIV/0!
M5W	0	0	0	0	0	0	0	0	667.488	0	0.00	#DIV/0!
M7N	0	0	0	0	0	0	0	0	174.046	0	0.00	#DIV/0!
M7S	0	0	0	0	0	0	0	0	310.039	0	0.00	#DIV/0!
H1		0	0	0	0	0	0	0	77.9776	0	0.00	#DIV/0!
H2		0	0					0	104.178		0.00	#DIV/0!
H3	0	0	0	0	0	0	0	0	34.3725	0	0.00	#DIV/0!
H6	0	0	0	0	0	0	0	0	306.92	0	0.00	#DIV/0!
H7	0	0	0	0	0	0	0	0	101.059	0	0.00	#DIV/0!

Figure 1A. Piezometer M-4

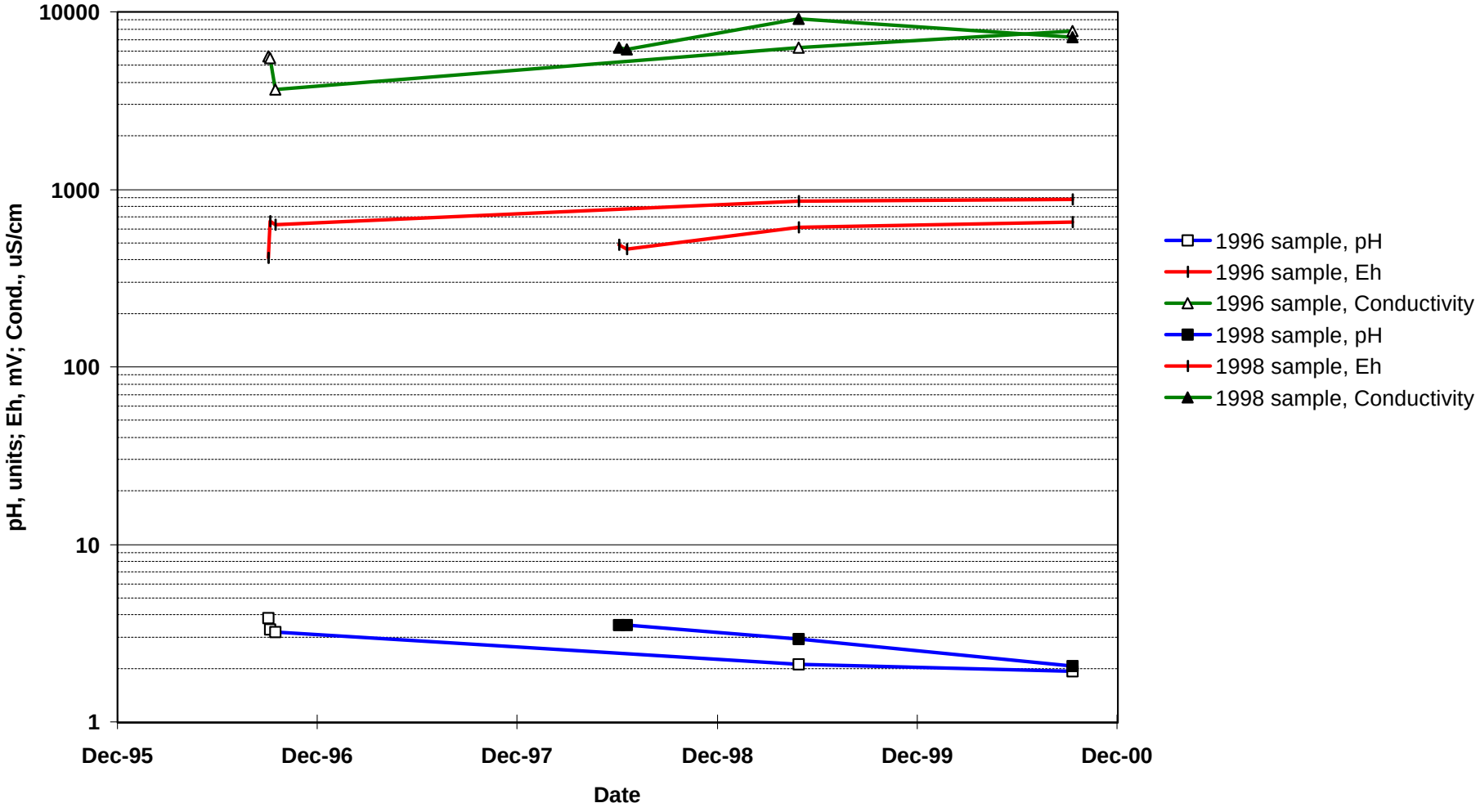

Figure 1B. Piezometer H-1

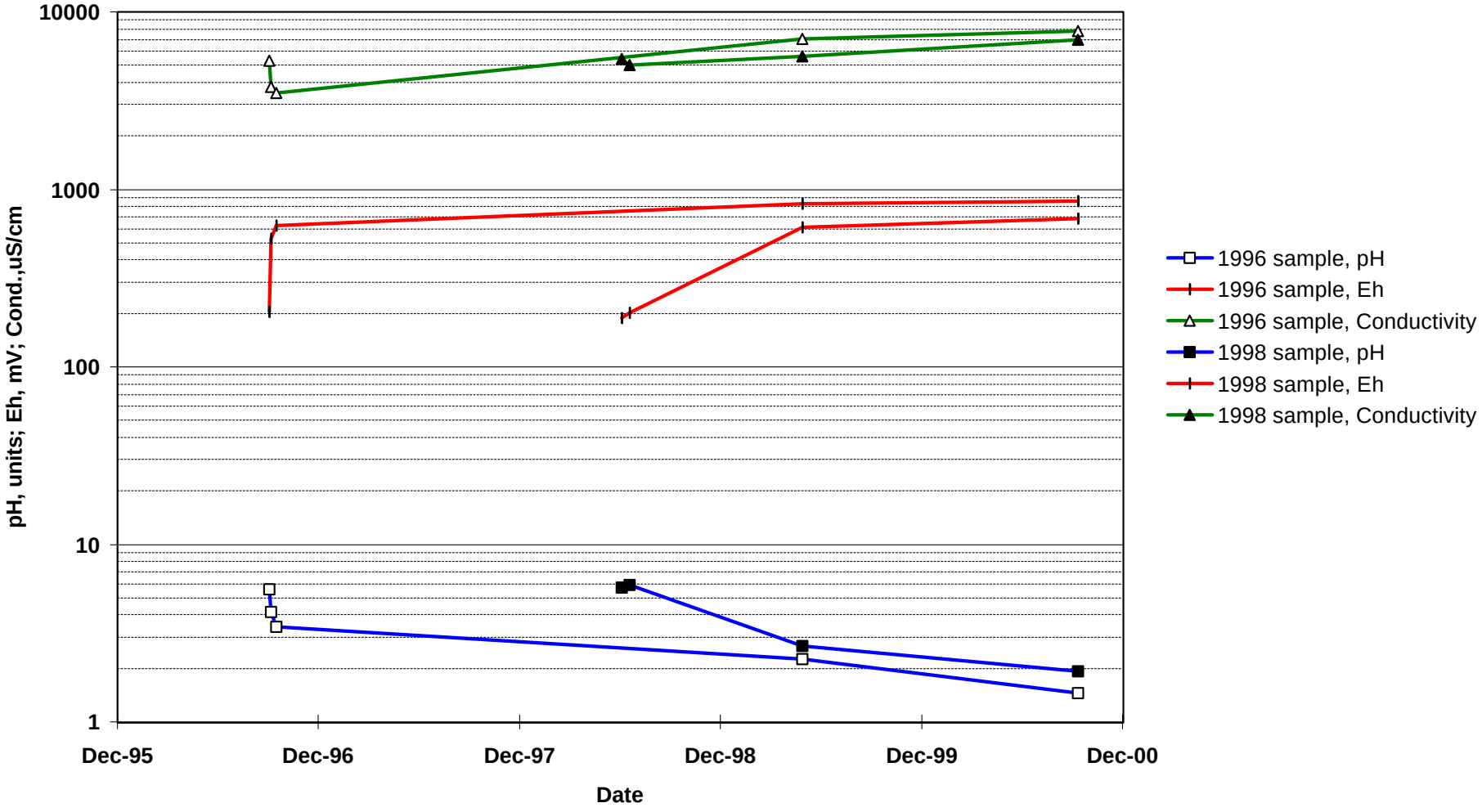

Figure 2A. pH History of 1996 samples

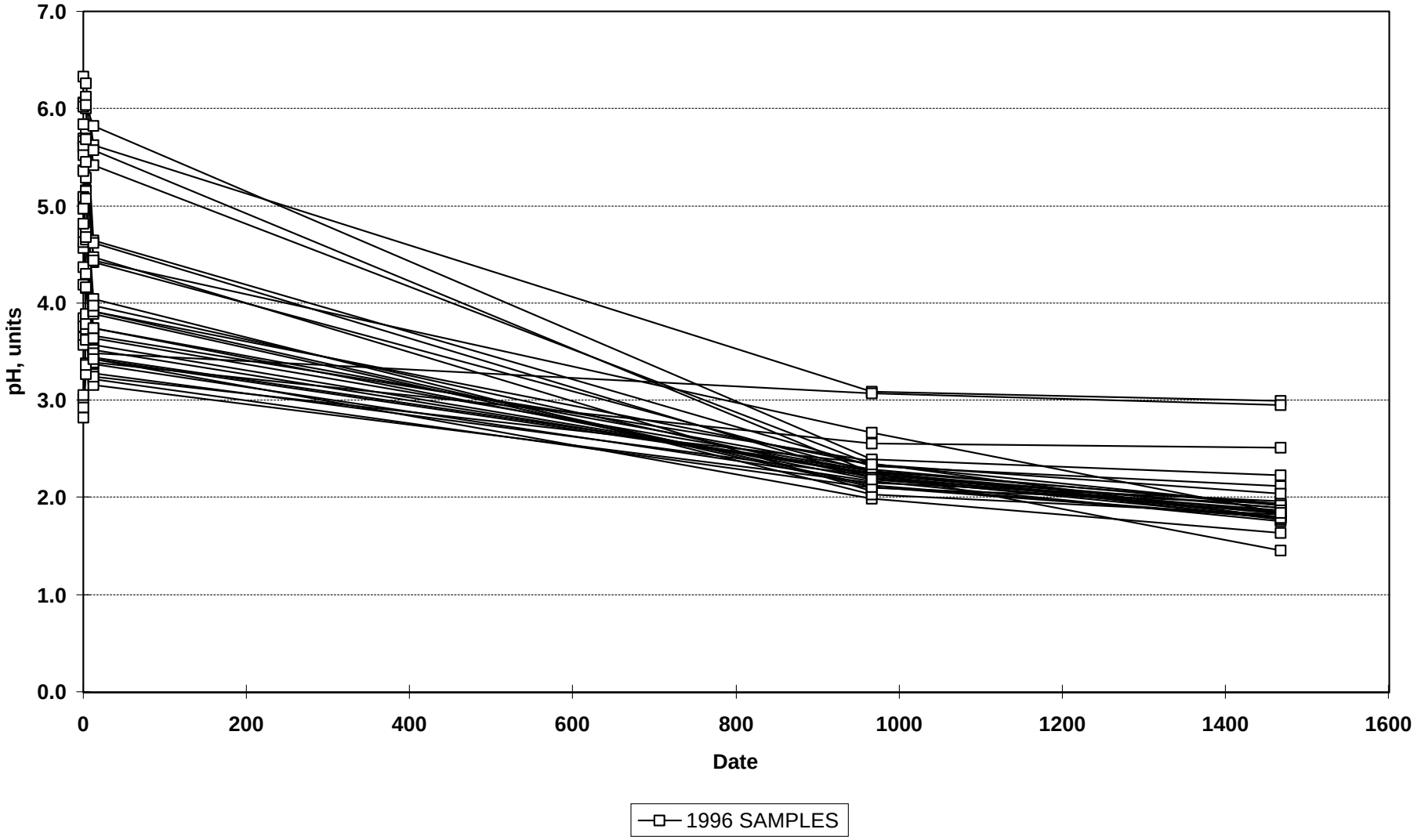

Figure 2B. pH History of 1998 samples

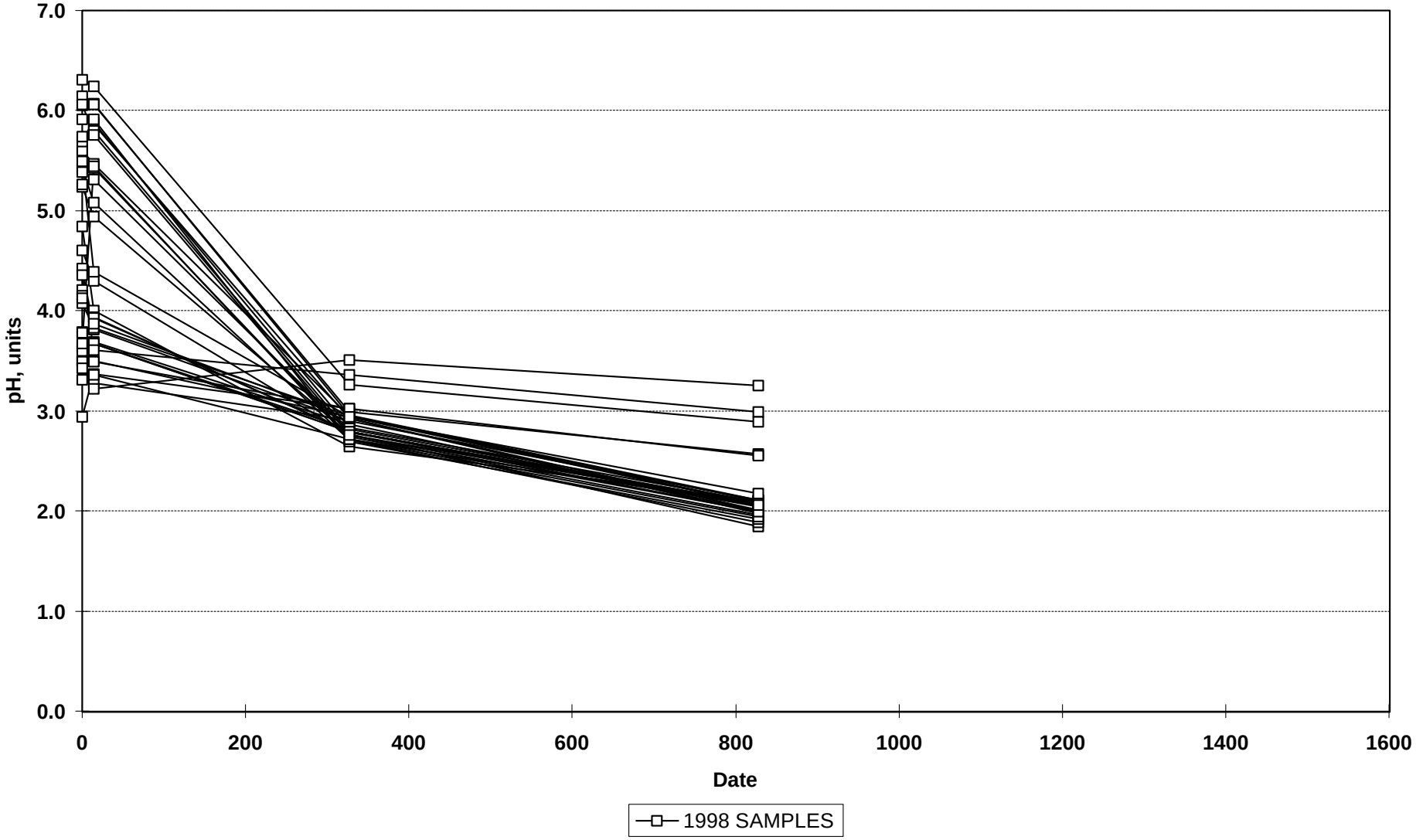

Figure 3A. Median pH, Eh & Conductivity Values for 1996 Samples

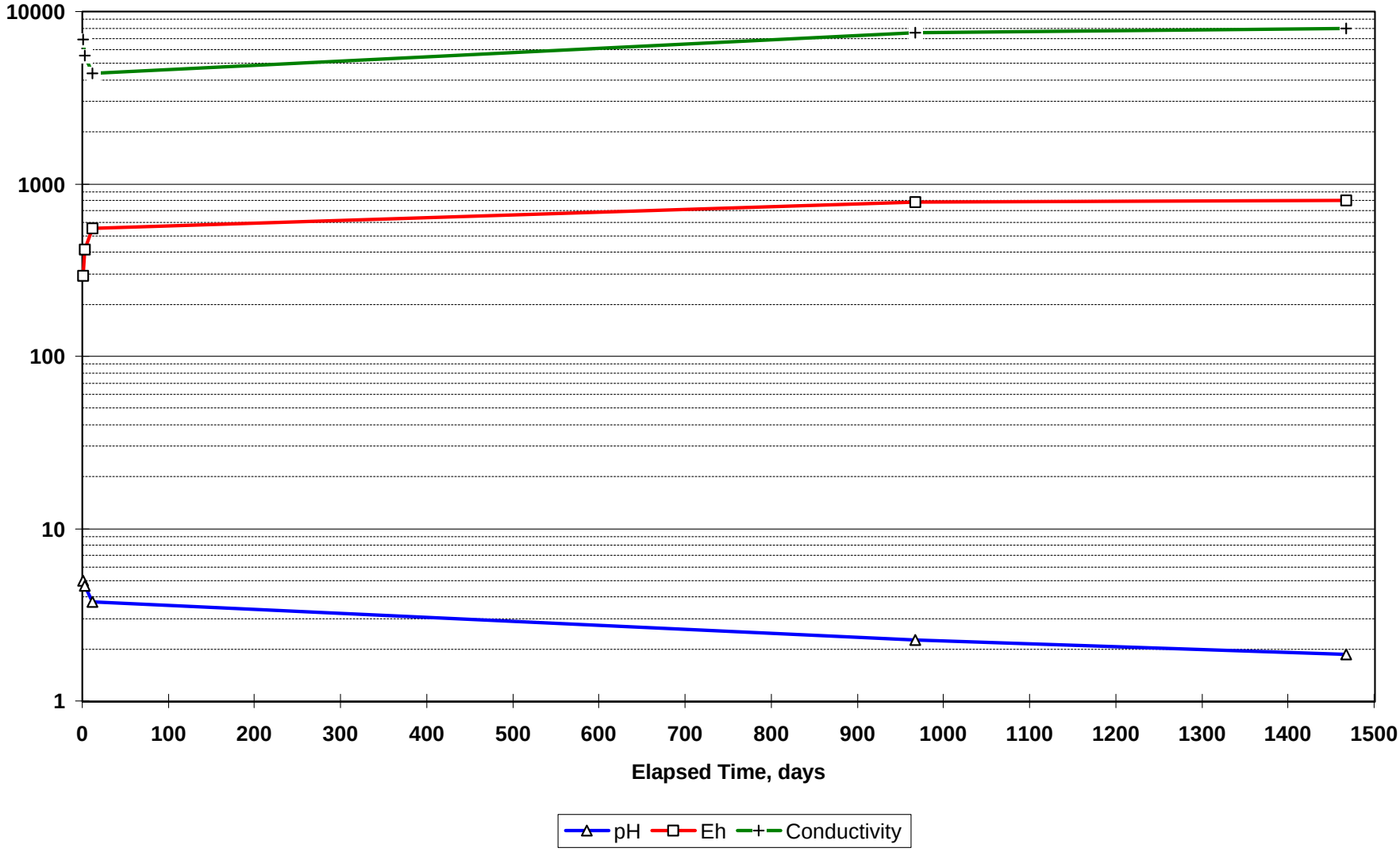

Figure 3B. Median pH, Eh & Conductivity Values for 1998 Samples

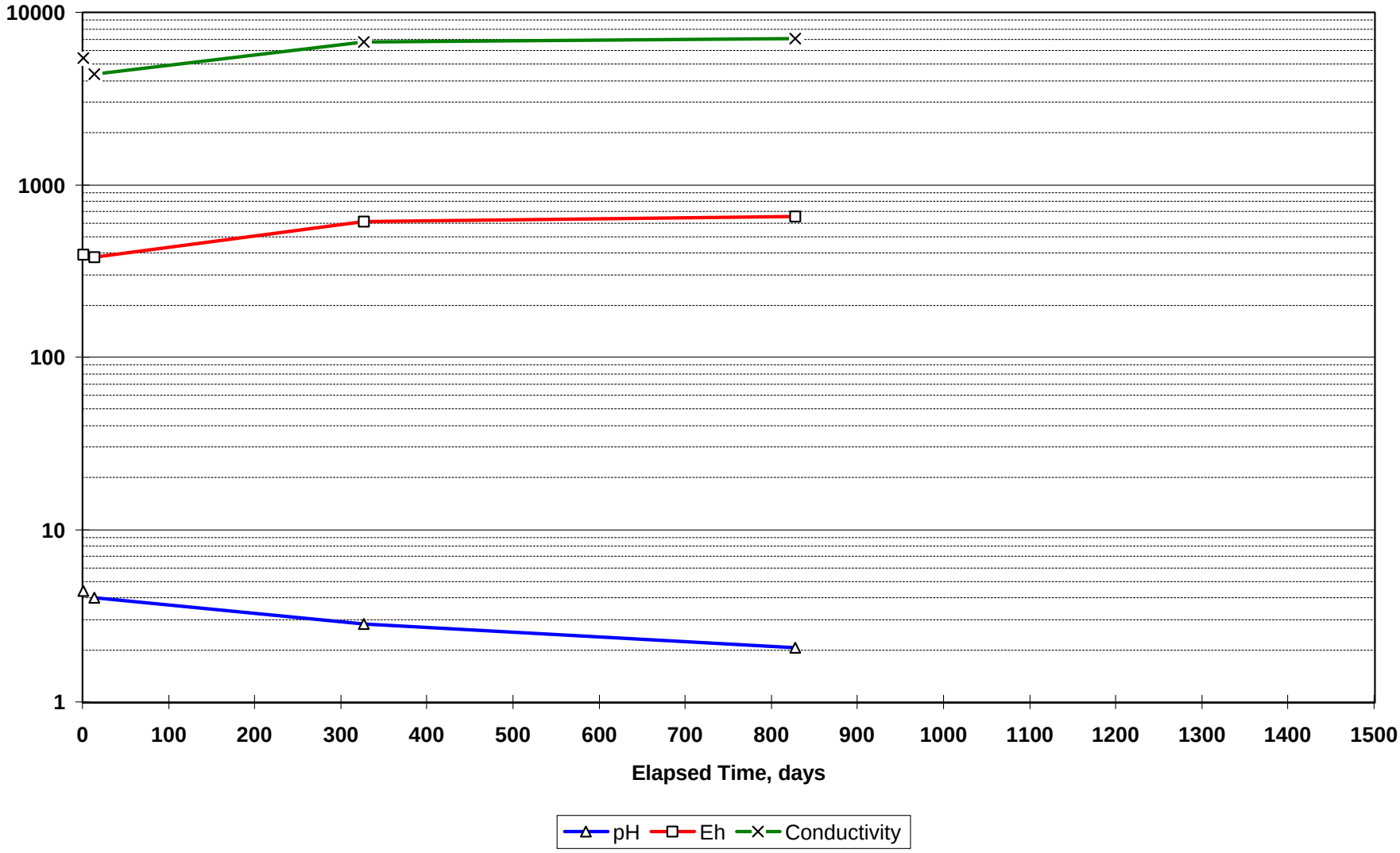

FIGURE 4. pH HISTORY and POTENTIAL pH DEVELOPMENT of SELECTED SAMPLES

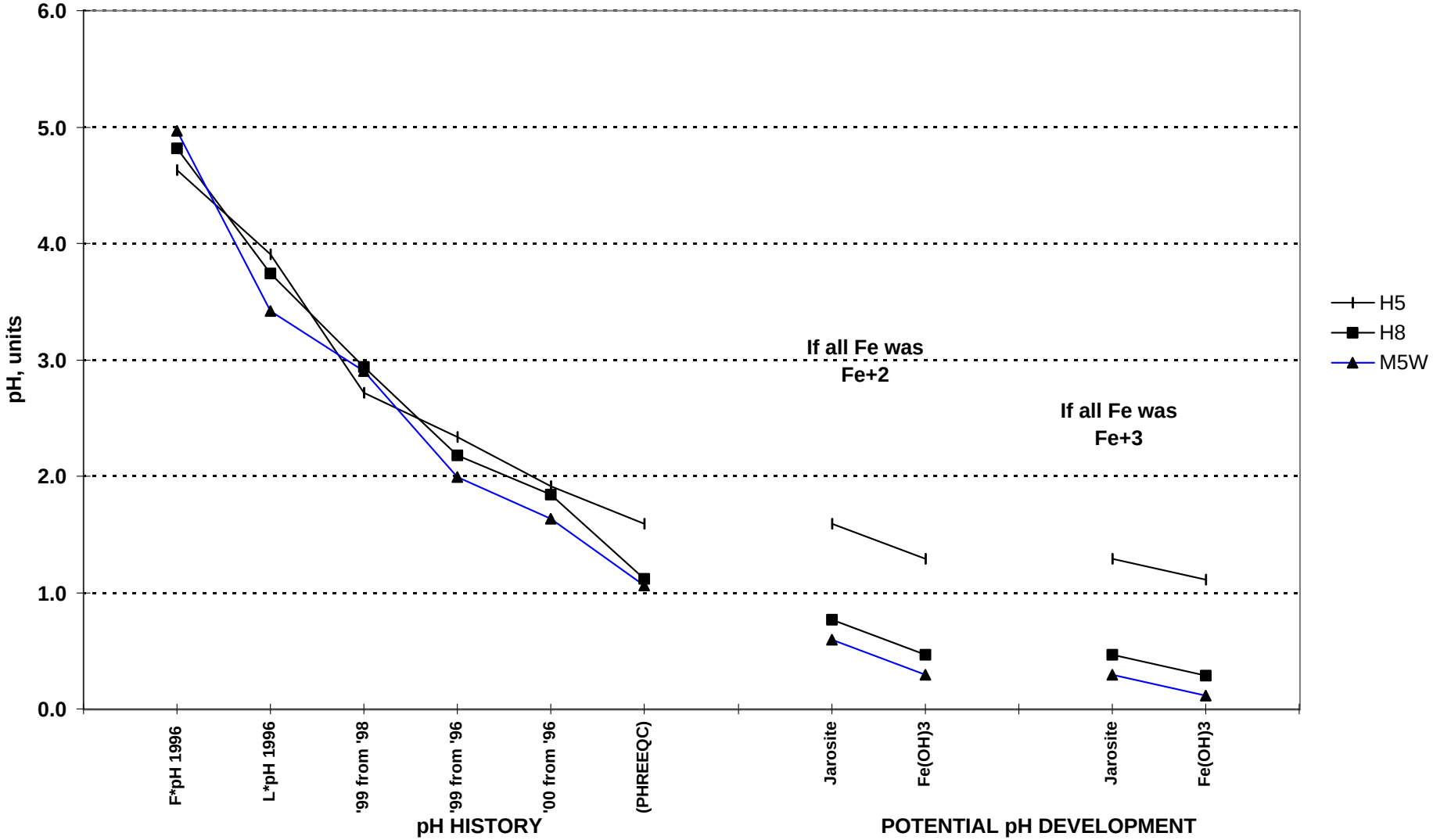

FIGURE 5. pH HISTORY and POTENTIAL pH DEVELOPMENT